



Spirometer

(Product No 3267)

Air Flow: ± 10.0 litres/second (l/s)

Resolution: 0.01 l/s



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Introduction

The *Smart Q* Spirometer is a differential pressure transducer that interfaces to a pair of flow heads to measure air flow rate. The Sensor works by measuring pressure drop across a reference flow resistance. An embedded microprocessor in the Spirometer converts the pressure readings into air flow rate. The air flow data can be converted to volume using a simple function in the **EASYSense** software before or after data collection, see page 4.

The Spirometer is supplied with a nose clip, 4 flow heads (one attached and three for test subjects) and a circular guard for the 'fixed' flow head (to prevent it being used). A flow head contains an antibacterial and antiviral filter to lessen the possibility of cross contamination between subjects. Two flow heads are attached to the Spirometer during use, one is kept fixed in place and the other is the test subject's flow head. To minimise the danger of cross contamination, the flow head used by the test subject is only for their own use and should be regarded as a 'disposable' item.

Note: *The air flow rate measurement is only valid if two flow heads are fitted to the Spirometer during use.*

Replacement packs of 10 flow heads (*Product No. 3269*) and 5 nose clips (*Product No. 3264*) are available from Data Harvest. Contact sales for further information.

Disclaimer

The *Smart Q* Spirometer is sold for the purpose of teaching and educational instruction. It is **not**, and has not been designed to be, a diagnostic tool. The results are illustrative only; any information gained from the use of this apparatus must not be used as the basis or any medical or clinical diagnosis.

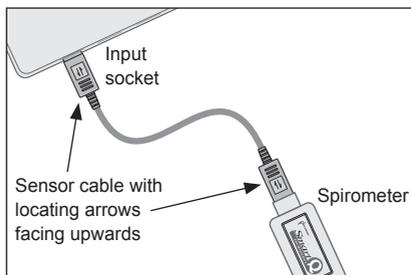
Read the instructions before use. Students should be supervised at all times.



Follow your local safety guidelines. It is the responsibility of the tutor to ensure that individuals using this apparatus are healthy and have no history of respiratory or cardiovascular problems. The students must be reassured about the medical validity of the results. Respiratory tests can be challenging, limit the number of tests in a session and take care that an individual is not overstressed by the tests.

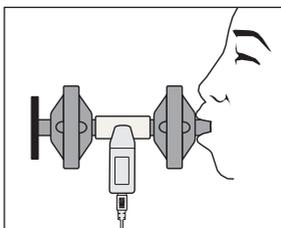
We do not recommend the use of this sensor with individuals under the age of 10.

Connecting



- Hold the Spirometer housing and push one end of the sensor cable (supplied with the **EASYSense** unit) into the hooded socket on the adaptor with the locating arrow on the cable facing upwards.
- Connect the other end of the sensor cable to the input socket on the **EASYSense** unit (with the locating arrow facing upwards). The **EASYSense** unit will detect that the Spirometer is connected.
- The 'fixed' flow head should be attached to the end of the housing tube that is marked by a cross (X) on the label. Attach the circular guard plate to this flow head to give a visual and physical reminder that it should not be used by a test subject.
- Mark another flow head with the test subject's name. Gently push the narrower tube of the test subject's flow head into the other end of the housing tube (indicated by a tick ✓ on the label) until some resistance is felt. The tube of the flow head is tapered and is not supposed to fit fully into the housing tube.

Measurement procedure



- Sit upright (with good posture) or stand comfortably. If possible look away from the computer screen so you cannot view the data as its being collected (so you won't subconsciously alter your breathing pattern).

- Hold the Spirometer in an upright position.
- Place the flow head's mouthpiece in your mouth, between the teeth, and make a good seal with your lips. Keep your tongue flat so it doesn't obscure the opening.

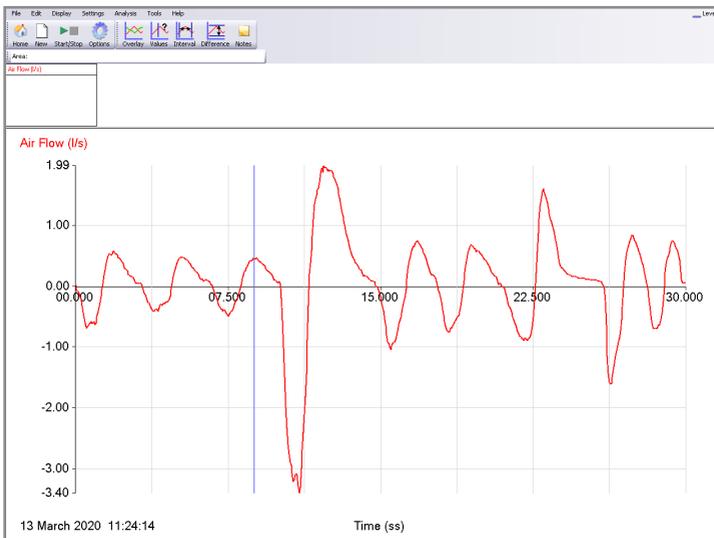
Note: You may find biting the flow head is a good way to hold it in position.

- If required attach the nose clip or hold your nose to ensure that all breathing is done through the mouth. (This is necessary if the results need to be qualitative, but is not normally required for breathing pattern studies).
- Make time to adapt to breathing into the flow head and practice any procedures you need to follow. You may find it easier to be talked through each part of the routine or to follow a card of instructions.
- Breathe quietly in order to become accustomed to the apparatus and attain a stable breathing pattern. Air expired from the lungs is measured as positive flow, inspired air as negative.
- Rest the Spirometer on the work surface between uses to prevent the heat of your hand affecting the results.

Note: Don't expect perfect results first time. The Spirometer is an unnatural breathing device and time is required to learn how to breathe naturally through it.

Air Flow vs. Time

Air flow is the rate of movement of air that flows in and out from the lungs, sometimes referred to as ventilation.



Converting air flow data to Volume

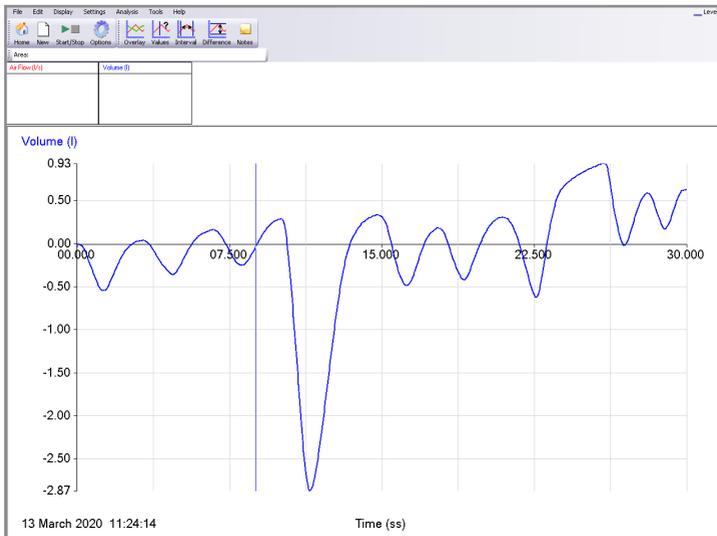
Volume shows the amount of air that has moved through the Spirometer, it therefore indicates the amount of air that has entered or left the lungs in that inspiration / expiration. Volumes in and out may not be equal; speech for example requires retention of air and controlled release. Over long periods the volume in should equal the volume out.

Note: The Spirometer Flow to Volume function is only available in V2.2 or higher of the **EASYSSENSE** software

- Select either **Pre-log** or **Post-log Function** from the **Tools** menu.

Note: The pre-log function will convert air flow to volume as the data is being collected. The post-log function is applied to air flow data after it has been collected.

- From **Preset function** select **Spirometer** from the first drop-down list and then **Spirometer Flow to Volume**, Next.
- Select the Air Flow channel to use, Next and then Finish



When the air flow data is converted to volume (using a pre or post-log function) you may find an upward or downward trend in the volume data. This is quite normal for an open flow spirometer. As long as the drift is no more than 0.3 litres in 30 seconds it can be ignored. If not use the post-log function in the **EASYSSENSE** software to apply a drift correction to the collected data, see page 8.

Health and Safety considerations

- The flow heads are capable of trapping sub-micron sized microbes. They have cross contamination efficiency for both bacteria and virus of 99.9% @ 55L/min and 750L/min.

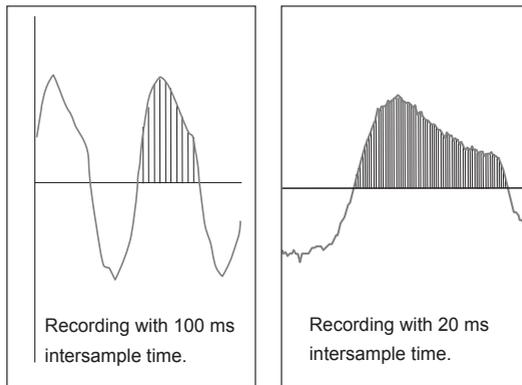
- Each student should use their own flow head. There is a possibility that infective agents trapped in the filter can become freed during inhalation and breathed back into the test subjects system. This represents a point of possible cross contamination. It is **not** sufficient to simply wipe the mouth piece of the flow head with an antiseptic wipe and pass the apparatus on to the next subject. This only cleanses the area in contact with the mouth, it does not disinfect the filter or the internal surfaces of the flow head.
- The 'fixed' flow head will not need to be changed with each use as long as the outlet side is protected by the test subjects flow head.
- If the 'fixed' flow head is accidentally used by a test subject then it should be replaced.
- Test subjects should not be overstressed by the activities that use the Spirometer. The instructor should make efforts to check the subject is healthy and has no history of cardiovascular or respiratory problems e.g. asthma.
- The nature of the Spirometer means that some subjects will feel discomfort when using the apparatus. Efforts should be made to put the test subject at ease. Stop the investigation if the test subject's discomfort becomes too great.
- The length of the apparatus should not be increased under any circumstance. The apparatus does not contain a flow control valve and therefore increases the anatomical dead space of the subject.

Practical notes

- Do not try to force the flow heads into the plastic moulding, this could damage the moulding and cover the sensing hole.
- Best results are obtained if the test subject has become used to breathing through the apparatus before commencing an investigation. A five minute acclimatisation period is recommended. With experience and practice the pattern becomes normal.
- It is quite normal for the test subject to experience increased salivation when they first use the Spirometer. Keep the flow heads in the upright position to avoid problems with condensation developing.
- After prolonged use the inside of the spirometer's housing tube may become coated with condensation. It is advisable to check for this occasionally and wipe away as needed. The amount formed will depend upon the temperature of the room and the level of breathing
- The nose clip is used to prevent air from entering or leaving the nose as the subject is breathing. It should be used if the results need to be qualitative, e.g. during volume measurements when the air that passes through the nose should not be included. For studies and comparison of breathing patterns a nose clip is not necessary.
- Make sure that when the Spirometer is in the test subject's mouth that there is a good seal and that the tongue is kept flat so it does not obscure the opening (they may find biting the Spirometer tube is the best position)
- Two small lugs are moulded into the housing tube; these have been provided for a thin line or lanyard (e.g. a glasses lanyard) to be attached to support the Spirometer during use.
- The flow heads carry the CE0086 quality mark and are made from plastic recycle type 5: Polypropylene (PPE). They also carry a ♻️ mark to indicate and confirm that they are for single use (individual) only.



- If the Spirometer is used with a data logger that records 10 bit instead of 12 bit data (e.g. **EASYSense** Flash, Q3 or Q5) the quality of samples will be lower. This will become more noticeable when data is used to perform calculations (e.g. to derive volume).
- A 20 ms intersample time (or less) is recommended for the best results.



Cleaning

- The housing tube and nose clip can be cleaned with a soft damp cloth using standard hospital grade disinfectant or a Milton type hypochlorite solution (made up using bottle instructions). Avoid using alcohol, which will eventually craze the plastic. Do not attempt to clean a flow head for reuse.
- Do not under any circumstances immerse the Spirometer or its flow heads into a cleaning liquid or attempt to sterilise with hot water, steam or air.

Background

The Spirometer is used to measure both the amount of air that moves in or out of the lungs and how quickly the air is expelled from the lungs.

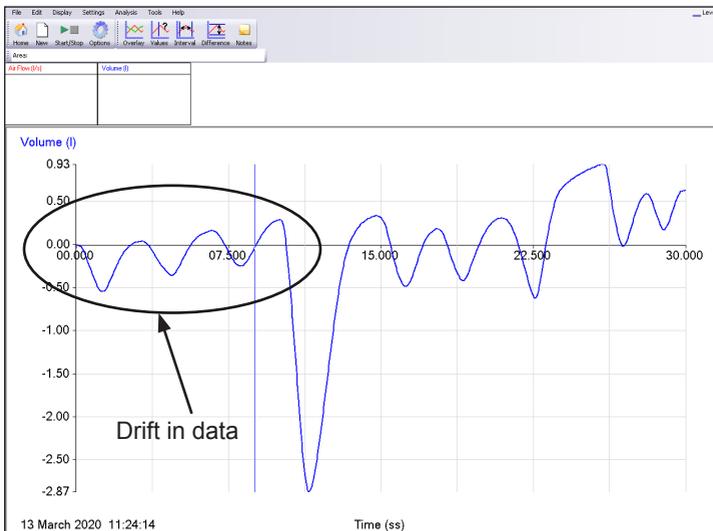
- The amount of air that moves in or out of the lungs during any one breathing cycle is called the **tidal volume**. Tidal volume is typically 0.5 litres.
- After normal inspiration it is possible to breathe in additional air - this is called the **inspiratory reserve volume**.
- Similarly, after normal expiration, it is possible to exhale additional air from the lungs - this is called the **expiratory reserve volume**.
- Even if the expiratory reserve volume is fully expelled from the lungs, there is still a volume of air in the lungs, called the **residual volume**, which cannot be exhaled. The residual volume has a very low oxygen and high carbon dioxide concentration.
- Upon inhalation fresh air mixes with stale air from the residual volume to create air in the alveoli that still has gas concentrations that facilitate the diffusion of oxygen into and carbon dioxide out of the capillaries.
- The respiration centre in the medulla ensures that gaseous exchange at the lung matches the requirements of the body. During times of increased demand, the tidal volume can be increased, using some of the reserve lung volumes to bring more fresh air into the body. In addition, the rate of breathing and the rate of air movement in and out of the lungs can be changed.

Table 1 Glossary

Term	Abbreviation	Description
Spirometric values	FVC	Forced Vital Capacity: the total volume of air that can be forcefully exhaled after maximal inspiration
	FEV₁ FEV₆	Forced Expiratory Volume in one second: the volume of air that can be exhaled in 1 second after a maximal inhalation Forced Expiratory Volume in 6 seconds
	FEV₁/FVC%	The Forced Expiratory Volume in one second as a percentage of the forced vital capacity
	MVV	Maximal Voluntary Ventilation: the maximum volume of air that can be exhaled under forced exhalation
	PEF or PF	Peak Expiratory Flow or Peak Flow: the maximum flow achieved at the beginning of the FVC manoeuvre
Lung volumes	ERV	Expiratory Reserve Volume: the maximum volume of air that can be exhaled after a normal end of expiration
	IRV	Inspiratory Reserve Volume: the maximal volume of air that can be inhaled after a normal end of inspiration
	RV	Residual Volume: the volume of air remaining in the lung after a normal exhalation
Lung capacities	TV	Tidal Volume: the volume of air that is inhaled or exhaled with each respiratory cycle whilst breathing without effort
	FRC	Functional Residual Capacity: the volume remaining in the lung after a normal end expiration
	IC	Inspiratory Capacity: the maximal volume of air that can be inspired from a normal resting expiratory level. $IC = TV + IRV$
	TLC	Total Lung Capacity: the volume of air in the lungs at maximal inflation
	VC	Vital Capacity: the largest volume measured on complete exhalation after full inspiration. $VC = TV + IRV + ERV$

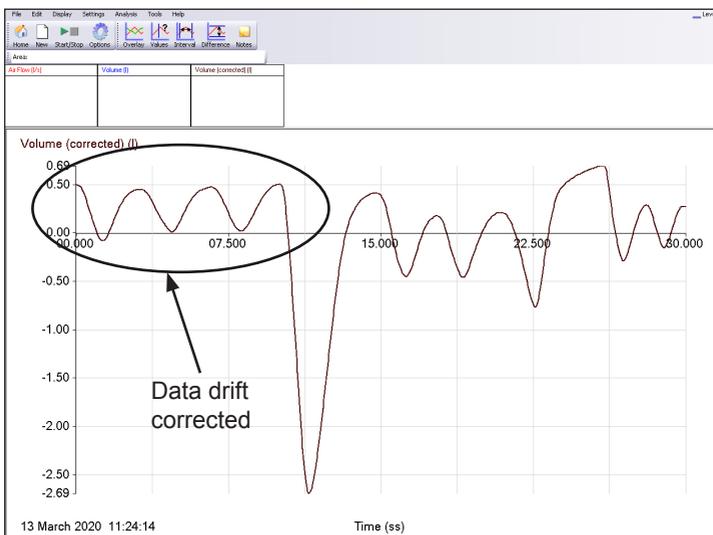
Logging functions

To correct volume data for drift



- From the **Tools** menu select **Post-log Function**.
- Select **Preset function, Spirometer, Spirometer Volume drift correction**, Next.
- Select the channel with the Volume data, Next. Alter the name to identify it as the adjusted data e.g. Volume adj. The best adjustment parameters will already be entered; they can be modified if required. Click on Finish to create the corrected data set.

Note: The drift correction will not be able to make adjustments for variable drift rates.



To correct the air flow data for a sensor offset

The pressure transducer in the Spirometer is very sensitive and may sometimes indicate a small flow when none is present. This can happen, for example, when the Spirometer is held at an angle or when the power supply of the logger is getting low.

- Make a note of the recorded flow when no air is moving through the Sensor (this will be the **Tare** value).
- From the **Tools** menu select a **Post or Pre-log Function** (pre-log to remove the offset as data is being collected, post-log to remove the tare from collected data).
- Select **Preset function, General, Tare, Next**.
- Select the channel to apply the tare to, Next. Alter the name to identify it as the adjusted data e.g. Air Flow adj. Enter the **Tare value** in the Parameters section (make the value negative or positive as appropriate). Click on Finish.

To convert the air flow data to volume using a spreadsheet

If the **EASYSSENSE** software is not being used the Air Flow data can be exported into Excel or a similar spreadsheet program to create, ventilation flow rate, breathing function, efficiency (Flow volume curves) and capacity graphs.

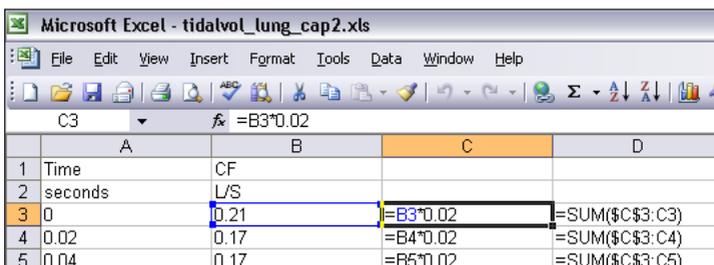
1. Select **Copy Table** from the **Edit** menu.
2. Open the spreadsheet application e.g. Microsoft **Excel** and select **Paste** from the Edit menu to insert the data.
3. The first two columns will be the data pasted in from Graph (Column A= the time data, Column B = the Air Flow data).
4. Enter the formula **=(A4-A3)*B3** into Column C to calculate the volume per time interval for the whole column (see tip below).

Note: B3 is the reference to the first cell that contains the air flow data. (A4 - A3) is the time interval between readings.

5. Enter the formula **=SUM(\$C\$3:C3)** into Column D to calculate the total volume changes for the whole column (see tip below).

Note: This formula adds the numbers between cells, the \$ sign keeps the starting point for the addition C3.

TIP: In Excel as you paste the cell you will notice a small + appear in the right hand lower corner of the cell you are pasting into, if you double click on the +, the formula will automatically copy down the whole column of data.



	A	B	C	D
1	Time	CF		
2	seconds	L/S		
3	0	0.21	=B3*0.02	=SUM(\$C\$3:C3)
4	0.02	0.17	=B4*0.02	=SUM(\$C\$3:C4)
5	0.04	0.17	=B5*0.02	=SUM(\$C\$3:C5)

Note: The View formula option has been set to reveal the formula for the screen grab.

- **Column A** is the Timing information from Graph in seconds.
- **Column B** is the Air Flow data from Graph in litres per second (L/s).
- **Column C** is the calculation for volume of air that has passed in the time interval between the data points (subtracts the times in column A from each other to find the time interval and then multiplies the time interval by the Air Flow rate to give the volume).
- **Column D** is the cumulative volume of air that has moved over the whole cycle. The total volume of air is added up or subtracted to give a rise and fall in volume.

Investigations

- *Breathing patterns before, during and after exercise*
- *Lung capacities*
- *Lung efficiencies FVC, FEV1 and FEV6, MVV*
- *Flow volume curves*
- *Slow Vital capacity (SVC): The user should breathe normally 3 times and then inhale to the maximum extent of total lung capacity and then expire to the maximum extent*
- *Maximal voluntary ventilation (MVV): The user should breathe as deeply and as rapidly as possible over a period of 6 to 12 seconds*

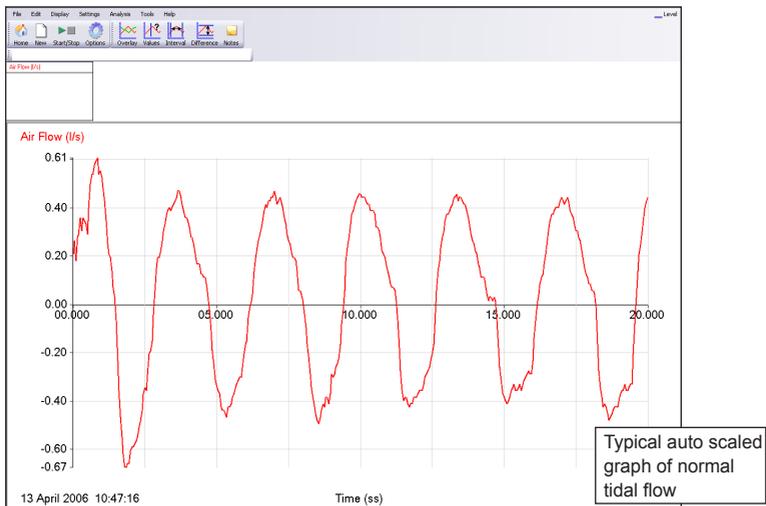


Note: Care should be exercised when performing this test as there is a danger of hyperventilation. Ensure the test subject is sitting down

Breathing patterns

Use the Spirometer to record the air flow whilst the test subject is at rest, exercising or recovering from exercise when the body's demand for oxygen has been elevated.

Right click in the graph area and use **Zoom** (or autoscale) to magnify an area of the graph.



Use **Interval** to find the length of time it took to complete a set number of breathing cycles e.g. how long it took to complete 5 cycles at the beginning, middle and end of the recovery time after exercise.

Use **Area** to calculate the area under or over the X-axis at different points to find the volume of a single expiration / inhalation.

Lung Capacity

In this investigation you are comparing your normal breathing pattern with the changes that take place with a deep breath in or out. For lung capacities measurement the breathing should be natural and progressive when conducting the deep inhalation / exhalation.

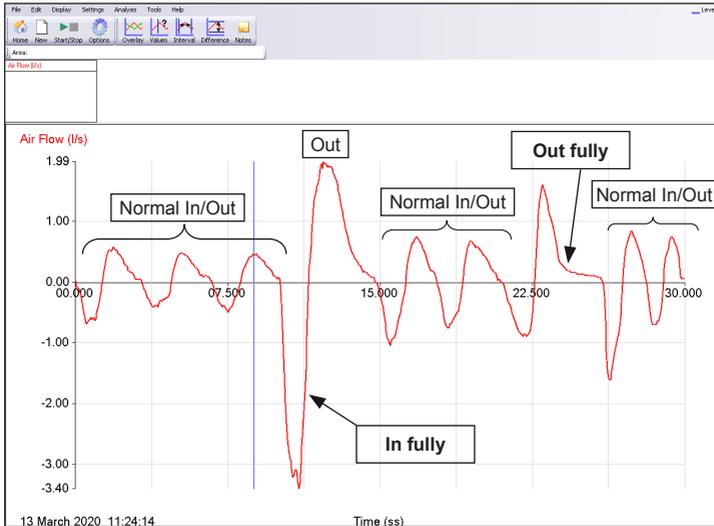
Let the test subject breathe through the apparatus for several minutes to get used to the apparatus. They should use a nose clip or hold their nose. It may be useful to get them to practice the deep inhalation and exhalation that is required for the investigation.

Note: *The exhalation and inhalation should not be forced, but they should be complete in this investigation. A complete exhalation / inhalation is reached when the subject feels they need to move from inhalation to exhalation or vice versa, they should not force breathing past this point in this exercise.*

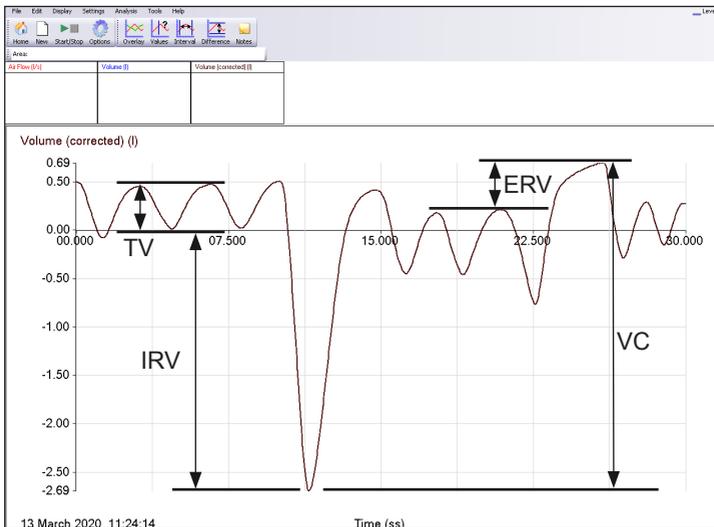
- Open the **EASYSSENSE** program and select **Graph** from the Home page.
- From the logging wizard select a recording time of **30 seconds** and an interval of **20 ms**. For a consistent start point set a start condition e.g. for when Air Flow falls below 0.2 l/s.
- Attach the nose clip or hold your nose. Place the Spirometer in your mouth and get used to breathing evenly and smoothly through the apparatus.
- Click on the **Start** icon.
- Take 3 - 4 normal breaths (this will establish the tidal volume) and at the top of the last expiration start breathing in - continue until it is felt that no more air can be comfortably inspired and then breathe out.
- Breathe normally for another 2 - 3 cycles, then at the peak of next inspiration breathe out as far as possible (let the breath out fully to the point of the natural need to inspire).

In / Out	In / Out	In / Out	IN FULLY	Out	In / Out	In / Out	In	OUT FULLY	In / Out	In / Out
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- Breathe naturally until the logging time is finished.



- Correct the air flow data for any sensor offset - see page 9.
- Apply the Spirometer Flow to Volume post-log function and create a Volume vs. time curve - see page 4. If the volume curve shows too much drift apply the Volume drift correction - see page 8.



The values for tidal volume, inspiratory and expiratory reserve volumes can be taken off the chart directly using the difference in volume between peaks and troughs.

Lung Efficiency (air flow / volume curves)

This investigation models the lung function tests carried out in many asthma clinics and sport fitness laboratories.



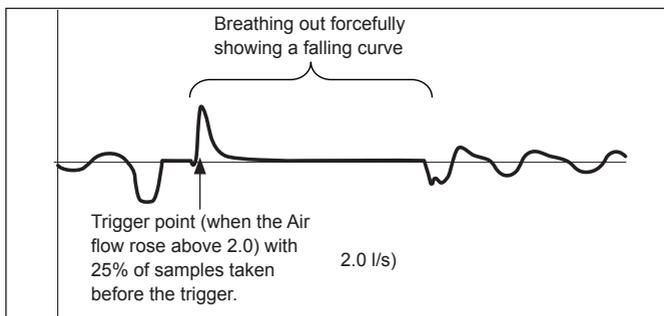
This investigation can be challenging. Care should be taken to ensure that the test subject is not overstressed by the tests. It is strongly advised that no one person should repeat the test more than 4 times in a session.

The test subject is required to take a very deep breath in followed by a rapid forced inhalation, both with maximal effort to clear and fill the lungs as quickly and deeply as possible. The critical phase of the investigation is the forced exhalation which should last at least **6 seconds** for lung efficiency values to be correctly calculated. For lung efficiency studies the test subject should be encouraged to breathe out from the diaphragm upwards, contracting the chest at the beginning of the forced exhalation may cause 'glottis closure' which invalidates the data (this will be seen as pronounced bump / platform in the falling edge of the data).

Investigation 1

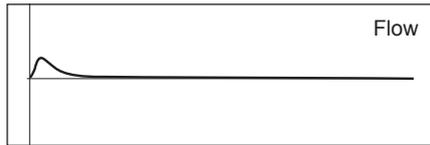
- Open the **EASYSSENSE** program and select **Graph** from the Home page.
- From the logging wizard select a recording time of **20 seconds** with an interval between samples of **10 milliseconds**, set a trigger of **Air flow rises above 2.0 l/s** with a **25%** pre-trigger.
- Place the Spirometer in the mouth, attach the nose clip and get used to breathing evenly and smoothly through the apparatus.
- Click on the **Start** icon. Fully inflate your lungs, and then breathe out as forcefully and for as long as you can (6 seconds minimum). Breathe in and then breathe normally until the recording is finished.

Breathe in fully	Breathe out forcefully for 6 seconds minimum	In	In/Out
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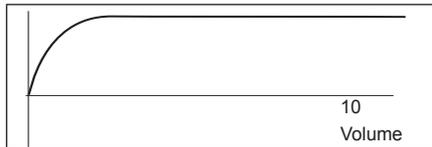


The data should show a line which shows a steep change (rise) in flow rate followed by a more gradual return to zero flow.

- Correct the air flow data for any sensor offset - see page 9.
- Select the data for the forced exhalation breathing cycle only (click on the first reading in the cycle, hold down and drag to mouse to the last reading). Click on **Use Selection** from the Edit menu to display the selected data only.



- Apply the Spirometer Flow to Volume post-log function and create a Volume vs. time curve - see page 4.

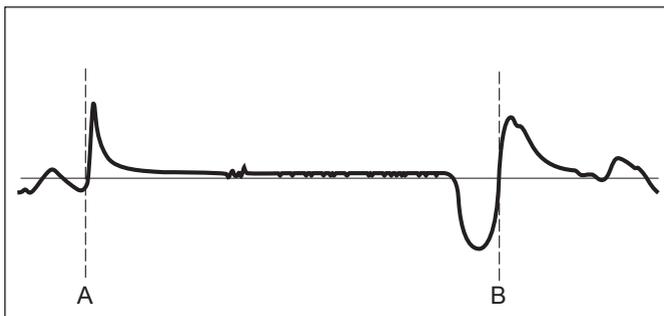


- Use Values and Difference to calculate the spirometric values defined in the glossary on page 7.

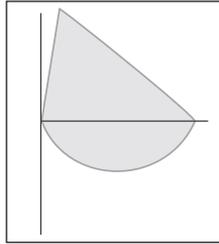
Investigation 2

- Use the same set up as Investigation 1.
- Click on the **Start** icon. Inhale into the Spirometer normally, then **exhale forcefully** and completely without hesitation for at least **6 seconds**, and then **inhale as deeply** and as quickly as possible.

In	Breathe out forcefully for 6 seconds minimum	Inhale deeply and quickly	In/Out
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- Correct the air flow data for any sensor offset - see page 9.
- Select the data from just before the beginning of the exhalation [A] to the end of the inhalation [B] (click on the first reading in the cycle, hold down and drag to mouse to the last reading). Click on **Use Selection** from the Edit menu to display the selected data only.
- Apply the Spirometer Flow to Volume post-log function - see page 4.
- If the volume curve shows too much drift apply the Volume drift correction - see page 8.
- Plot an XY graph with Volume on the X-axis vs. Air Flow on the Y-axis (select Options, X-Axis, Channel, and OK. Click in the area to the left or bottom of the axis to alter the channel displayed).



The shape of the slope can give an indication of the type and seriousness of any lung disease (the term disease does not always indicate a problem; it is often used by medical practitioners to indicate a change from the ideal state). The slope for an individual with no lung disease will descend in a straight line down to zero. Any curving of the slope is an indicator of:

- Poor technique in the patients use of the equipment
- Poor elasticity of the lung.
- Obstruction of the airways.
- Asthma.

Note: *The identification of any pulmonary disease requires a high level of training and medically calibrated equipment. Results from this exercise should be illustrative and not considered as a diagnostic.*

Warranty

All Data Harvest Sensors are warranted to be free from defects in materials and workmanship for a period of 12 months from the date of purchase provided they have been used in accordance with any instructions, under normal laboratory conditions. This warranty does not apply if the Sensor has been damaged by accident or misuse.

In the event of a fault developing within the 12-month period, the Sensor must be returned to Data Harvest for repair or replacement at no expense to the user other than postal charges.

Note: Data Harvest products are designed for **educational** use and are not intended for use in industrial, medical or commercial applications.